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General cargo and containership emergent routes: A complex networks description

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ABSTRACT

The paper aims to explain the evolution of the containerized and general cargo maritime routes in the last 3 years using complex networks analysis. Several particular results are searched: which ports are currently rising or dwindling in throughput; how is the structure of their network dynamics; and how to describe the resemblances and differences between these two transport patterns.

In a densely connected logistic scheme, like the current maritime transport network, classic statistical techniques cannot show an accurate measure of the regional and global importance of a port or a route, within the deeply interrelated global market. The influence of a given harbor must be put in relation with the whole set of the network nodes. Standard statistic tools also cannot explain the chronological evolution of a complex system such this, needed of an importance metric and a proper visualization treatment.

Graph theory provides powerful mathematical tools in order to achieve such requirements. Several calculations (degree and centrality) can be performed on each node, in order to describe clearly the structure and evolution of the complex system formed by ports of call and routes performed between them. Besides this, new software representation tools, like Gephi and Tulip, allow the immediate and deep comprehension of the relations between all the elements of the graph computed, and the temporal evolution of the whole network.

In this paper we will apply these methodologies to the entire database of containership and general cargo vessel positions in three periods: March 2008–February 2009, March 2009–February 2010 and March 2010–February 2011. The relevance of the time intervals for this analysis, in terms of length and immediacy, will lead us to an accurate and dynamic diagnostic for the evolution during the crisis years in the transport patterns of the two traffics considered.

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1. Introduction

Precisely how, when, and the state in which developed countries emerge from the current economic crisis is the subject of intense debate. This controversy is reflected in the divergent macroeconomic data series forecasts obtained by different financial institutions with respect to trends in commercial trade. This data is being constantly updated and revised in consonance with the volatility currently buffeting economic scenarios.

The goal of this research is to provide evidence as to the way in which both general and containerized traffic has evolved between 2008 and 2011. According to data from UNCTAD (2010), containership transport has increased significantly since the 1960s when it first came to be an integral part of maritime trade. By the year 2005 the containership fleet already had a larger capacity than that of the general cargo class. Since then, this difference has increased until the present day when 8.48% of global deadweight tonnage (henceforth d.w.t.) is carried using general cargo vessels, while 13.26% is transported by containership. However, between 2007 and 2009 (UNCTAD, 2011) variations in the volume of orders for the building of the two types of vessels have been quite different. The number of orders for the former has increased by 13.91%, while, for the latter there has been a decrease of 43.34%. This information forms the basis for the hypothesis formulated in this analysis, namely that the crisis in demand has affected these two modes of maritime transport differently.

It would have been possible to verify this hypothesis by using statistical analysis techniques to express the features of each unit and then to carry out quantitative comparisons. It was decided instead, however, to use a technique that looks at complex networks. The main goal was to set out the interrelations that exist between a given port and the global set of nodes that exist

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within the network. In order to do this it was first necessary to obtain a measure of the local importance of each port and a suitable visual representation of the complex network. The main thrust of the work carried out here is closely connected to the ideas of degree and centrality. These concepts allow the analysis to build a measurement framework which is capable of explaining a large proportion of both global and local activity for a certain position or geographical region.

2. Antecedents

There are various key contributions to the study of transport and complex networks. There are four complementary areas of knowledge used as the cornerstones of this work.

First, there is the economic theory that underlies marine and maritime analysis. There are many important contributions within this area, studies that often include swathes of economic estimators and temporal series and which provide accurate knowledge with respect to certain concepts such as the market for the sale of ships, freight indexes and the size of the active world fleet. So comprehensive are these sources, that it is sometimes rather difficult to isolate the main pool of information (UNCTAD, IMO, IMF, World Bank). Key works in this area include those of Goss (1977), Stopford (1997), Branch (1998), McConville (1999) and Freire and González (2009). A special mention should also be given to the approach undertaken by Rodrigue et al. (2009) which is both encyclopedic and methodological and addresses the geo-logistical problems that are part and parcel of the modern challenges posed by multimodal goods transport. Hayuth (1981) and Slack et al. (2002) on the other hand, look at new ports and emergent regions.

Second, the analysis also rests upon more specific works that look at the dynamics of port regionalization processes (hinterland–foreland interaction phenomena).These are important for the accurate economic interpretation of the market relations that exist in a given geographical area. Notteboom and Rodrigue (2005) explains the working structure of ports clusters, and conceives of the current phase of activity as the extension of inter-port commercial relations beyond close-range geographical influence towards the foreland. The work of Fremont (2007) contains answers to questions thrown up by the polarization of the specialized Northern Range trade centers. Along similar lines, De Langen (2003) identifies port clusters as the main unit of analysis, while Hayuth and Fleming (1994), McCalla et al. (2005), Ng (2006) and Ducruet (2008) provide new perspectives from which to study the optimal localization of hubs.

Third, it is important to cite the works that deal with complex maritime networks. Ducruet et al. (2010a, 2010b, 2010c) and Kaluza and Kölzsch (2010) establish the basis of this methodology, both in terms of the definition of key concepts, the correct procedures for analysis and, the levels of rigor and precision of the quantitative techniques themselves. Fourth, graph theory has also played an important role in clarifying some of the questions arising from the complex systems analyzed in other academic, theoretical and practical levels. The study of scale free networks, such as those analyzed in this research, constitutes a novel, innovative area of scientific knowledge. This discipline came into its own with the work of Barabasi and Albert (1999) and has recently become an important focus of multidisciplinary development. Different perspectives have included work on internet technologies (Franceschet, 2011), human mobility patterns (González et al., 2008), social sciences (Eagle and Pentland, 2006; Pentland, 2006; Lazer et al., 2009), public health (Dey and Estrin, 2011), neuroanatomy (Joyce et al., 2010), information technologies security (Altshuler et al., 2010; Wang et al., 2009) and economy (Hausmann et al., 2011).

3. Sample composition

The sample used in this analysis was obtained from the Lloyd's Register database for the geographical location of vessels and is known simply as the Automatic Identification System[2] (henceforth AIS). This database has been used by many authors to describe maritime transport trade networks for several different classes of vessel (Kaluza and Kölzsch, 2010; Ducruet et al., 2010a, 2010b).

Table 1 provides the main features of the positions set used in the network analysis. Inclusion in the sample depended on criteria that looked at; the construction of vessels (from 1967 to 2009), whether or not a vessel was "in service", and a minimum size of vessel—a measure that aimed to eliminate coastal navigation and short-range maritime transport activity which would not be relevant for a global maritime analysis. Hence, only general cargo vessels over the average capacities (38,622 Gross Tonnage—GT hereafter), and containerships of over 6176 GT were selected.

The sample was divided into three time periods. The first takes in April 2008–March 2009 (08_09 henceforth). According to UNCTAD data, in terms of capacity, this period covers 22.07% of total extant general cargo vessels and 59.80% of the total current containership fleet. The second period from April 2009 to March 2010 (09_10 hereafter), saw similar proportions of the two types of vessels: 33.37% and 57.65% respectively. For the third period from April 2010 to March 2011 (henceforth 10_11), there is, as yet, no conclusive data. However, similar percentages are expected, in consonance with statistical accuracy.

The total number of general cargo vessels considered varied between 1515 and 1654 (08_09 and 10_11 respectively) while the numbers of container ships were 1164 and 1342 (08_09 and 10_11 respectively).

The increasing number of ports available for the general cargo class (938 in 08_09, 1232 in 09_10 and 1302 in 10_11) indicates that, even during a pervasive economic crisis, there have been a growing number of geographical positions that have begun to use general cargo transport. The scenario with respect to container-shipping is quite different; 330 in 08_09, 536 in 09_10 and 390 in 10_11 in which there was an important decrease in the number of ports of call registered. This does not necessarily imply that there was a decrease in activity for container shipping but a possible contraction in the location of containerized activity, as will be shown over the course of this article.

Each of the periods analyzed was subject to four refinement processes, or filters. The first of these involved removing all of the AIS positions for straits, channels and anchorages. While these data might be extremely useful for other kinds of study, they are useless for measuring the relevancy of ports in a given region. It is evident that the Strait of Malaca, and the Suez and Panama Canals are the main AIS positions for both maritime networks. However, these registered positions do not operate as commercial ports (Ducruet, 2010c) and are irrelevant, since the object of this analysis is to uncover economic and geographic explanations for maritime traffic. The most significant example of this, is the Hong Kong–Malaca Strait–Jebel Ali route, which we have termed Hong Kong–Jebel Ali, with the aim of expressing the relative real weight of the link between the two ports.

A second refinement consisted of eliminating all of the distortions that might have arisen due to the geographical proximity of terminals, as was the case of the sequence

[2] Automatic Information System (AIS): Traceability system that automatically reports call and departure data to the port authorities. Almost all modern vessels have this security device.

Table 1
Sample composition.
Source: Lloyd's Shipping Register, own elaboration.

Type of vessel analyzed	General cargo			Containerships		
Time scope sample	April 2008–March 2009	April 2009–March 2010	April 2010–March 2011	April 2008–March 2009	April 2009–March 2010	April 2010–March 2011
Number of vessels analyzed	1515	1578	1654	1164	1231	1342
Number of positions analyzed	83,057	102,330	119,217	113,125	128,230	151,422
Average number of calls per year	54	64	71	97	103	112
Maximum vessel capacity	49,370 dwt	49,370 dwt	51,624 dwt	15,550 TEU	15,550 TEU	15,550 TEU
Minimum vessel capacity	6179 dwt	6179 dwt	6179 dwt	1104 TEU	1104 TEU	1104 TEU
Total fleet capacity present in sample	23,284,510 dwt	24,360,830 dwt	25,946,904 dwt	6,434,923 TEU	7,000,233 TEU	7,946,910 TEUs
Total world fleet capacity estimated[a]	105,492,000 dwt	108,881,000 dwt	n/a	10,760,173 TEU	12,142,444 TEU	n/a
Number of different ports of call (nodes)	938	1232	1302	330	536	390
Number of links between ports (edges)	8857	12,487	14,181	2511	3355	3057

[a] UNCTAD (2010, 2011).

Table 2
Adjustment with real cargo data for the 25 main ports.
Source: American Association of Port Authorities, own elaboration.

Main containership ports			Main general cargo ports		
Position	TEUs throughput estimated	Real TEUs throughput	Position	DWT throughput estimated	Real TEUs throughput
Singapore	27,946,876	25,866,600	Singapore	30,917,648	47,230,000
Hong Kong	26,059,836	21,040,096	Shanghai	26,009,416	50,571,500
Rotterdam	17,063,396	9,743,290	Rotterdam	16,918,724	38,695,700
Hamburg	9,780,812	7,007,704	Antwerp	10,811,577	15,780,700
Chiwan	9,178,402	18,250,100	Tianjin	9,613,896	38,111,000
Shanghai	9,132,470	25,002,000	Moji	8,246,797	8,494,100
Busan	8,982,646	11,954,861	Yokohama	7,301,245	11,552,900
Qingdao	8,496,203	10,280,000	South Louisiana	6,956,156	19,285,300
Port Said	8,034,112	3,300,951	Houston	6,755,829	19,172,900
Savannah	7,527,376	2,356,511	Guangzhou	5,723,339	36,400,000
Felixstowe	7,054,050	3,100,000	Kobe	5,712,788	7,702,700
Antwerp	6,586,094	7,309,639	Durban	5,454,395	3,741,900
Le Havre	6,413,686	2,240,714	Hong Kong	5,378,904	24,296,700
Valencia	6,275,818	3,653,890	Saigon	5,085,851	3,300,000
Jebel Ali	6,266,933	11,124,082	Qingdao	4,667,818	27,430,400
Oakland	6,120,964	2,045,211	Mumbai	4,642,591	5,454,000
Tanjung Pelepas	6,025,101	5,835,085	Hamburg	4,274,736	11,038,100
Tianjin	5,827,235	8,700,000	Dalian	4,204,135	20,400,000
Los Angeles	5,563,492	6,748,994	Busan	3,893,833	22,618,200
Bremerhaven	5,356,191	4,578,642	Philadelphia	3,705,570	4,876,300
New York	5,028,793	4,561,528	Brisbane	3,597,662	3,211,900
Yokohama	4,943,881	2,555,000	Santos	3,343,201	8,319,400
Kwangyang	4,175,502	1,810,438	Tanjung Priok	3,298,679	4,154,600
Zeebrugge	3,907,294	2,328,198	Port Kembla	3,194,912	3,104,500
Kobe	3,881,413	2,247,024	Ulsan	3,130,577	17,031,400

"…-Apapa-Lagos-Apapa-Lagos-Apapa-…" and "…-Pernis-…-Rotterdam-…-Pernis-…-…-Rotterdam-…". These positions represent different locations within the same terminal; hence, presenting them as different ports would constitute a significant source of error. Therefore, the first sequence mentions only the "Lagos" positions, while the second contains only those of "Rotterdam".

A third refinement involved eliminating the ports that would have been repeated in different sequences. This measure aimed to avoid distortions with respect to the maximum capacity measured for each of the ports.

Lastly, connections were considered to be "undirected". For example, this means that no distinction was drawn between the "GioiaTauro–La Spezia" edge and "La Spezia–Gioia Tauro" for example. This is essentially a methodological refinement linked to the lack of information in the AIS registries with regard to the real quantity of goods transported via the given route, since this is a datum which is highly illusive. This fine-tuning means that the maximum capacity of the vessel may be taken to be the most accurate measure of the quantity of goods transported.

Once refined the initial dataset, graph theory is used in order to assess the behavior of each sample. It should be stressed that the relative weight of the traffic for a given port is computed by adding its total inbound and outbound capacities. In Table 2 (Fig. 1) it can be observed that the lineal concordance between the estimated capacity in the 09_10 period and real throughput data for the same time period is relevant. The values obtained for R2 are 0.813 for containerized operations and 0.713 for general cargo.

4. Methodology

The methodology used starts from the mathematical concept of networks understood as an ordered pair of two sets: one of nodes, and another of the relations between those nodes (edges).

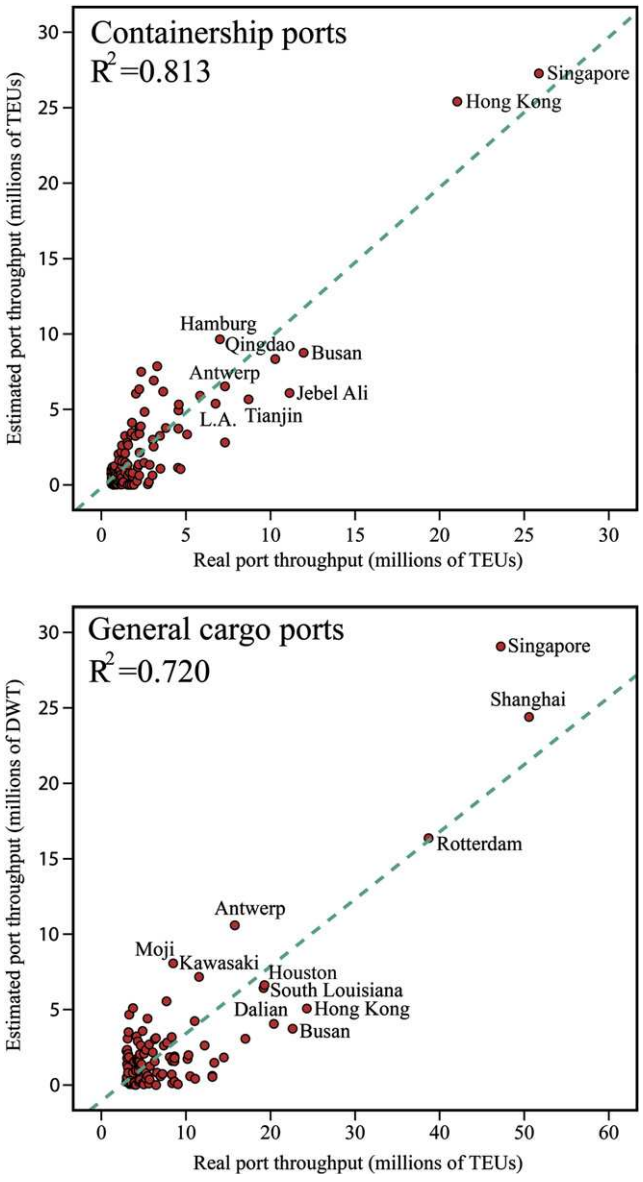

Fig. 1. Lineal adjustment with real cargo data.
Source: American Association of Port Authorities, own elaboration.

Once the database has been cleaned and filtered, and the AIS positions (nodes) for each vessel class refined, the network structure is built up using a postgresql server. This platform allows the analyst to perform the procedures needed in order to define the adjacency matrix, a mathematical construct that contains information relative to the connected nodes and the weight of their links. In order to calculate the different indicators, the Gephi network analysis tool was used (Bastian et al., 2009).

Firstly, it should be underlined that the concept of density may be used as an accurate measure of the global interconnectedness of the nodes within the network structure. A graph has density 1 if all its nodes are connected to one another. However, in the case of maritime transport networks some nodes tend to act as regional distribution centers and, as such, display high levels of connectivity, while others act as mere stop-over ports and have relatively few destinations for their foreland (Fremont, 2007). Given a graph (V,E), where V is the set of nodes and E the set of edges, the density is calculated using the following formula:

$$Density = \frac{2|E|}{|V|(|V|-1)}$$

Another robust, yet simple approach to network topology can be obtained using the concept of the average path length (henceforth APL). This indicator expresses the mean number of nodes needed in order to join any given pair of positions. When the APL decreases this means that there are more peripheral ports forming part of the kernel of the global supply chain and hence it is easier for clients to reach any position. The distance between two nodes v_i and v_j defined as $d(v_i, v_j)$ and the total number of nodes $|V|$ allow us to compute the APL:

$$APL = \frac{1}{|V|(|V|-1)}\sum_{i,j} d(v_i,v_j)$$

An indicator which is widely used in this study is that of degree which is crucial to the computation of the network's centrality coefficients, and affords access to the main topological properties. Given the network (V,E) and $v_i \in V$, the neighborhood of v_i is defined as $N_i=\{v_j / e_{ij} \in E \text{ or } e_{ji} \in E\}$ where $e_{ij}=\overrightarrow{v_i v_j}$. Under these conditions the degree (or degree of centrality) of a node is the total number of connections that it has with the other nodes in its neighborhood, hence $\text{degree}(v_i)=|N_i|$.

In a random network, in which all the nodes have approximately the same number of connections, erasing one of the positions significantly increases the APL, and it is said that the graph is vulnerable to random perturbations. However, in the maritime transport graph which is a connected graph, there are many nodes that are not relevant, and their suppression has no effect on the apparent structure of global trade. There is a small set of central nodes that exist within these networks which is critical in maintaining the topology. These types of network constitute an emergent field of research in graph theory and are normally termed "small world networks". They can be detected by using the average clustering coefficient or ACC. Under these circumstances, given a node v_i and its neighborhood N_i (which is directly linked to the nodes v_j), the calculation of the ACC is carried out as follows (Watts and Strogatz, 1998):

$$ACC = \frac{1}{|V|}\sum_{i=1}^{|V|}\frac{2|e_{jk}|}{k_i(k_i-1)} \text{ with } e_{jk} \in \left\{\overrightarrow{v_j v_k} \in E / \{v_j, v_k\} \subset N_i\right\}$$

The ACC is an indicator that reveals the presence of groups of self-differentiated (clusters) within the graph. If this value is computed for a random network made up of the same nodes, the resulting figure is much lower than that obtained for the (V,E) network calculation. This means that there exists a "small world network" for the graph being considered.

The other key indicator for this study is centrality, which, unlike degree, relates to the importance that the connections can have within the global scheme of paths and weights defined by the network, using this information as weighting criteria (Newman, 2008). Hence, a port with a high-level of centrality will be situated at the intersection of a large number of routes within the network, acting as a hub to the ports situated within its hinterland. When there are low values of centrality however, this does not necessarily mean that the market position is any worse (Ducruet, 2010a) but rather that the port has a special geographical location, located within an inner area of continental waters for example, or closer to positions which are much more important in terms of capacity.

Methods for calculating centrality are a branch of discrete mathematics, and one of the reasons for the entrepreneurial success of internet search engines which depend on algorithms to identify the most relevant pages for a requested search

Table 3
Topological parameters of the networks analyzed.
Source: Own elaboration.

Type of vessel analyzed	General cargo vessels						Containerships					
Sample	08_09		09_10		10_11		08_09		09_10		10_11	
	Mean	Gini	Mean	Gini	Mean	Gini	Mean	Gini	Mean	Gini	Mean	Gini
Throughput	566,594	0.7736	515,111	0.7567	590,430	0.7409	1,004,910	0.8464	685,875	0.8738	1,180,623	0.8293
Degree	19	0.5998	20	0.6020	22	0.5780	15	0.5848	13	0.6344	16	0.5701
Betweenness centrality	828.797	0.8691	1097.291	0.8745	1155.782	0.8719	272.552	0.8314	475.873	0.8900	318.980	0.8567
Maximum degree	Rotterdam (302)		Singapore (376)		Singapore (416)		Singapore (128)		Singapore (171)		Singapore (152)	
Maximum bet. centrality	Singapore (83,780)		Singapore (133,899)		Singapore (181,898)		Singapore (9557)		Singapore (24,466)		Singapore (13,725)	
Normalized bet. centrality	0.0098		0.0081		0.0063		0.0508		0.0194		0.0232	
Graph density	0.0200		0.0160		0.0170		0.0460		0.0230		0.0400	
Average Path length	2.7690		2.7827		2.7767		2.6568		2.7856		2.6399	
Clustering coefficient	0.425		0.426		0.418		0.581		0.629		0.593	
Diameter	7		6		6		6		7		6	
Radius	4		3		3		3		1		3	
Number of shortest paths	878,906		1,516,592		1,693,902		108,570		285,690		151,710	

(Brin and Page, 1998). There are two main approaches to the calculation of the centrality of a given node. The first consists of performing algebraic transformations in the set of eigenvalues and eigenvectors for the adjacency matrix. This technique has been shown to be efficient in the resolution of problems related to networks that accept states of connectedness that may be more than simply binary relations (Bonacich, 2007).

The second approach, used in this research, is the idea of betweenness centrality (henceforth BC) (Freeman, 1977). This indicator counts the number of occurrences of a given port within the set of all the shorter trajectories connecting any two nodes. It is therefore, a "crude measure of the control that exerts over the flow of information (or any other commodity) between others" (Newman, 2008). It must be highlighted the recent works published by Puzis et al. on the algorithm methods for the optimal calculation of this indicator (Puzis et al., 2012) or for to solve sensitive issues like the measuring of road traffic flow using mobile phones GPS data (Puzis et al., 2012). The formula used in this article (Brandes, 2001) is as follows:

$BC(v)=\sum_{s\neq v\neq t\in V}\sigma_{st}(v)/\sigma_{st}$ where σ_{st} is the set of shortest paths from the node s to the node t, and $\sigma_{st}(v)$ the number of shortest paths from the node s to the node t passing through node v. In order to calculate these paths the Dijkstra algorithm is used (Dijkstra, 1959).

This indicator is utilized for environments in which there are problems of geographical or informational flux, where it is important to consider the question of the shorter trajectories visiting a given node and where there can be nonegative weights (Ducruet et al., 2010a, 2010b; Kaluza and Kölzsch, 2010).

5. Topology of the general cargo and containerized networks

In Table 3 (Fig. 2) the main topological features of the network are presented. First, the mean capacity of each port is analyzed. The variable reflects a recovery in both types of mode of transport. This increase was lower in standard cargo transport which rose by 4.2% during the period studied while the comparative increase relative to containerships was 17.48%. This difference suggests that containerized traffic operators reacted with greater impetus to the decrease in demand.[3]

[3] 'The comeback kings', *Containerisation International*, March 2011.

Second, the analysis now looks at the way in which the mean degree changes. With respect to general cargo the indicator evolves positively throughout the period analyzed, indicating an enlargement of the foreland associated with each port. The scenario with respect to containerships was somewhat different. The foreland for these vessels contracted during the 09_10 period, but recovered and surpassed previous levels during the 10_11 period.

The centrality of general cargo ports has increased over the period analyzed, and the recession seems to have had only a mild impact on these firms. However, the sectoral crisis has affected a variety of processed products transported via containerships and this has meant that there has been a significant loss of mean centrality for the 10_11 sample ports when compared to the 09_10 period. In short, the general cargo terminals have had few strategic losses with respect to their forelands, while the containership terminals registered a local maximum in 09_10, which indicates that there are nodes whose growth has been significantly curtailed.

There is also an analysis of the betweenness centrality normalized with respect to its maximum value. This indicator facilitates a comparison between the two modes of transportation. The data for general cargo reflects decreases for the two periods considered of −17.34% and −22.46%. The decrease for containerized traffic, however, was of a magnitude of −61.81% in the first period with a slight recovery of 19.58% in the second. Therefore, the data clearly points to the fact that containership transport has been much more severely affected by the crisis in world demand.

Next, the graph density is analyzed in order to obtain the magnitude of the interconnection for each of the network nodes. The intermediate period 09_10 reflects a relative minimum for both modes of transport, and this corresponds to a key period in which there was a loss in the number of commercial links between ports. The situation improved during the last of the periods considered, thanks to an increase in the activity of the busiest routes.

Finally, the evolution of the Gini index provides a further perspective from which to view the network topology. This indicator reflects an increasing dispersion in the amount of goods transported (throughput) and in the scope of the foreland (degree), a tendency which is diametrically opposed to the proliferation of hubs (Ducruet, 2010a). It is always the containerships that glean the highest Gini values, which is consistent with the hub&spoke structure of this mode of transportation.

6. Geography of the network

An initial approach to a significant visualization of the networks studied can be adopted by using the geographical coordinates of each node. With the aim of reflecting any increase or decrease in the maximum capacity of the routes over the three periods analyzed, the logarithmic rates of variation (LRV) for the weight of each edge of the graph are computed. Figs. 3 and 4 (Table 4) represent the set of raw data corresponding to percentile 0.9, and aim to highlight the main trade flows. If we analyze the variation in the capacity of the routes it can be shown that, despite the stagnation (logarithmic rate of variation close to one), there are several lines in which traffic is increasing in both modes of transport.

The graphs show that, on the one hand, traffic across the Pacific Ocean is, in the main, containerized. This is due to the important weight of value added goods traded between both sides of this ocean. This contrasts markedly with general cargo transport, which is much more diversified and complex when it comes to loading, unloading and trans-shipment.

In contrast, trade via general cargo proliferates between the African and South American Coasts. The big hubs of the African West Coast (Lagos, Dakar, San Pedro, Douala, etc.) have not, as yet, become part of the globalized chain of container routes. Rather, their route takes them past the Cape of Good Hope, an alternative which has become increasingly important due to congestion and problems of piracy in the Gulf of Aden.

In the graph representing general cargo, one can visualize other areas in which traffic has increased significantly. The routes that stand out are the lines joining Valparaíso (Chile) with Callao (Perú) and the Panama port of Balboa; the Durban–East Asia connection; the

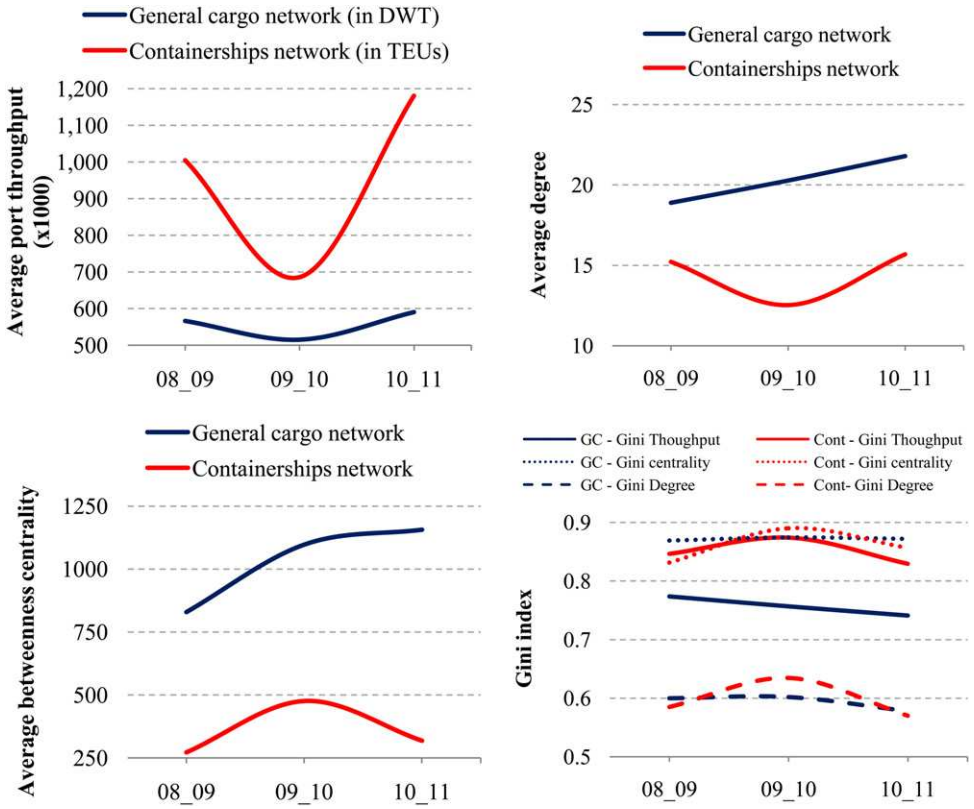

Fig. 2. Main topological parameters of the networks analyzed.
Source: Own elaboration.

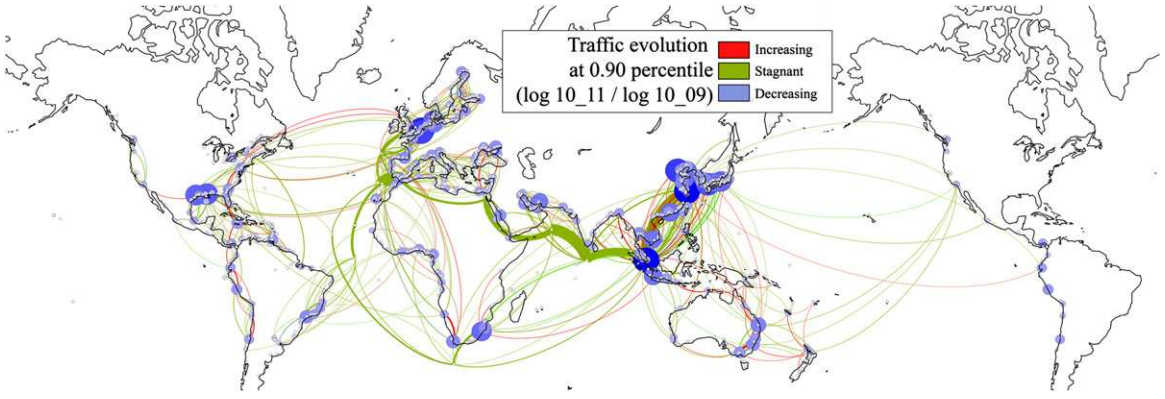

Fig. 3. Routes for general cargo ships in 10_11 from the 0.90 percentile.
Source: Own elaboration.

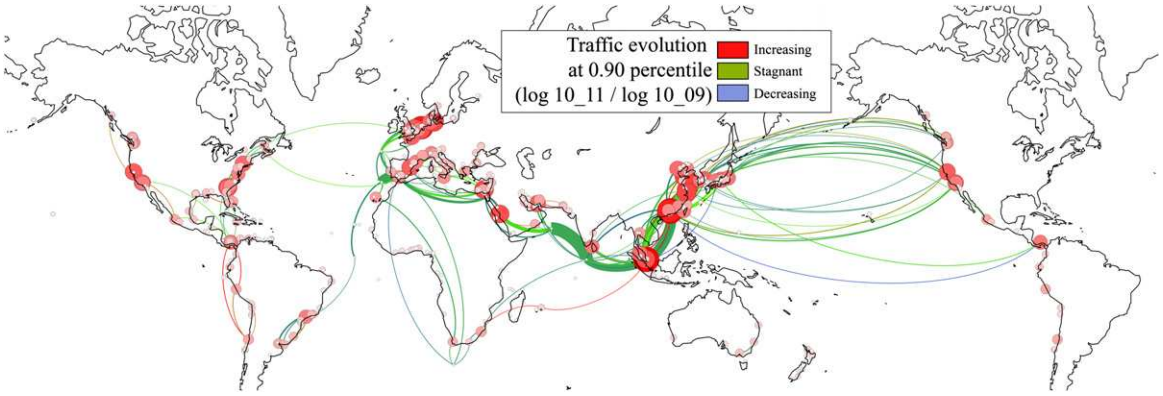

Fig. 4. Routes for containerships 10_11 from the 0.90 percentile.
Source: Own elaboration.

Table 4
Top 25 Routes (edges) with more logarithmic rate of variation (LRV[a]).
Source: Own elaboration.

General Cargo routes				Containership routes			
Position 1	Position 2	Edge weight (TEUs × 1000)	LRV	Position 1	Position 2	Edge weight (TEUs × 1000)	LRV
Singapore	Laem Chabang	1110	1.2816	Cristobal	Balboa	956	1.2406
Bangkok	Saigon	449	1.2173	Yokohama	L. Cardenas	210	1.2286
Bangkok	Singapore	491	1.2153	Barbours Cut	Savannah	188	1.2175
Tanjung Priok	Belawan	616	1.2048	Napier	Otago	100	1.2170
Taranto	Mariupol	367	1.1994	Otago	Timaru	95	1.2137
Wakamatsu	Hibikinada	190	1.1717	Las Palmas	San Pedro (Iv. Coast)	74	1.2074
St Petersburg	Kronshtadt	1174	1.1710	Rotterdam	Caucedo	97	1.2053
Durban	Beira	340	1.1652	Ambarli	Port Said	168	1.2026
Varna	Kerch	493	1.1555	Lagos	Lome	76	1.2024
Hirohata	Himeji	1143	1.1549	Karachi	B. Abbas	436	1.2019
Map Ta Phut	Saigon	228	1.1495	Durban	Port Louis	322	1.2015
Tianjin	Kwangyang	288	1.1492	Miami	NY & NJ	161	1.1978
Qingdao	Sungai Paking	108	1.1486	Jebel Ali	Sharjah	55	1.1923
Kobe	Ulsan	139	1.1462	Cartagena	Cristobal	29	1.1905
Qasr Ahmed	Homs	148	1.1461	San Pedro (Iv. Coast)	Douala	55	1.1887
Guayaquil	Callao	939	1.1442	Dakar	Abidjan	63	1.1881
Ube	Moji	112	1.1431	Klaipeda	Gdynia	66	1.1876
Napier	Tauranga	389	1.1421	Tanjung Pelepas	Johor	57	1.1875
Onne	Malabo	204	1.1415	Shimizu	Kobe	362	1.1867
Varna	Mariupol	705	1.1397	Chiwan	Kwangyang	147	1.1864
Cote–Sainte–Catherine	Hamilton (Canada)	145	1.1397	Westport	Tanjung Pelepas	714	1.1825
Belawan	Tanjung Perak	103	1.1365	Philadelphia	Colon	56	1.1818
Siam Seaport	Kashima	147	1.1359	Iquique	Arica	50	1.1796
Kingston	Paramaribo	205	1.1346	Montreal	Liverpool	233	1.1780
Walvis Bay	Cape Town	1487	1.1344	Shimizu	Nagoya	370	1.1746
Average for all edges		76	1.0020	Average for all edges		265	1.0109

[a] Given the capacity of one route in 08_09, c08_09, and the capacity of the same route in 10_11, c10_11, the Logarithmic Rate of Variation is ln(c10_11)/ln(c08_09).

entry to the Straits of Hormuz; and the New Orleans–Freeport (Bahamas)–Savannah line. The growth in America is closely linked to the forthcoming opening of new channels in the Panama Canal, which is promoting considerable improvements in the installations and draughts of several American ports.[4]

7. Visualization of the gravity model

There is a further method via which these logistical chains may be analyzed besides simply using geographical distances (Kaluza and Kölzsch, 2010). The gravitational model applied to the vessel positions sample is based on the calculation of the force of attraction joining two given ports when the following variables from the graph are taken into consideration: capacity and the "weight" of the edge. The former represents the "mass" in the Newtonian model (which means that large mass exerts a greater gravitational force than a small one). The second variable measures the distance traveled between the two positions measured in terms of units of capacity transported; "distance" between masses in the Newtonian model. If the geographical network is allowed to evolve via algorithmic separation (Hu, 2005), the nodes and the edges become relocated in a state of equilibrium which is represented in graphs 5, 6, 7 and 8.

The dynamics of the evolution of general cargo from 2008 to 2011 (Figs. 5 and 6) are characterized by several significant

[4] 'An expanding brief', *Containerisation International*, July 2010.

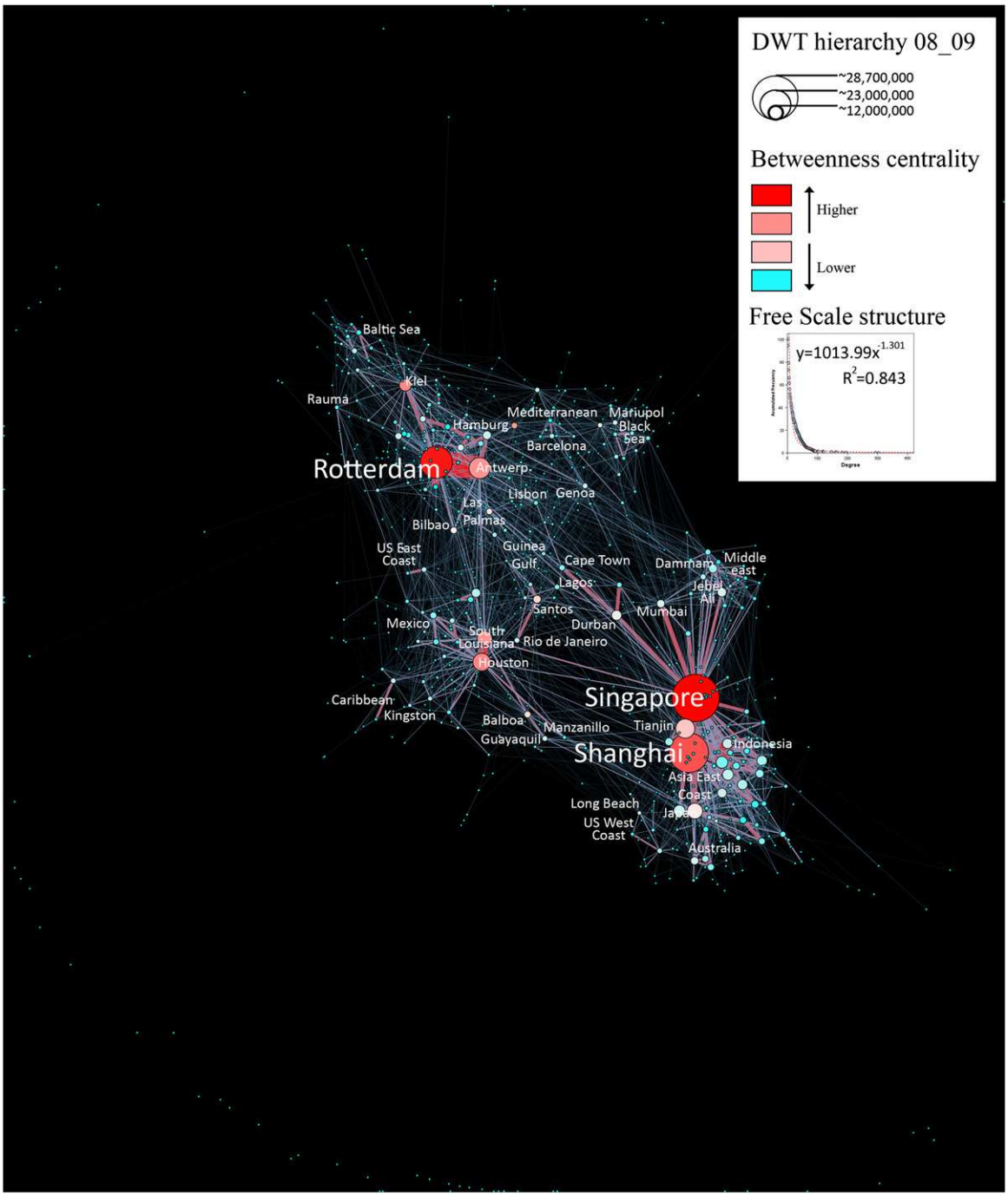

Fig. 5. Separation of 08_09 general cargo graph.
Source: Own elaboration.

changes. The most important of these is a perceptible de-clusterization or redeployment, the effects of which can be observed, for example, in the expansion of the Central-American region, where there are several strongly emergent areas of activity, and in the reinforced link between the East Coast of the USA and the Caribbean, South America and the African Atlantic coasts.

The two key axes of general cargo transport, Rotterdam–Antwerp and Singapore–Shanghai, have experienced an increase in the volume of their regional trade relations, characterized by links to a growing number of subsidiary ports. This suggests that current internal demand stimulus policies may have led the new big clusters to channel more port resources towards importation rather than exportation.

With respect to the connections between the former meta-hubs, there has been an observable reinforcement in supply routes via the Cape of Good Hope. The graphs also register the emergence of wide channels of communication via the Saudi port of Jeddah, and a strengthening of the connection between the East and West Atlantic coasts. Communications between East Asia and America have fallen off dramatically however (Singapore–Houston line), and only the line that joins Guayaquil–Valparaíso to the Asian side of the Pacific Ocean remains.

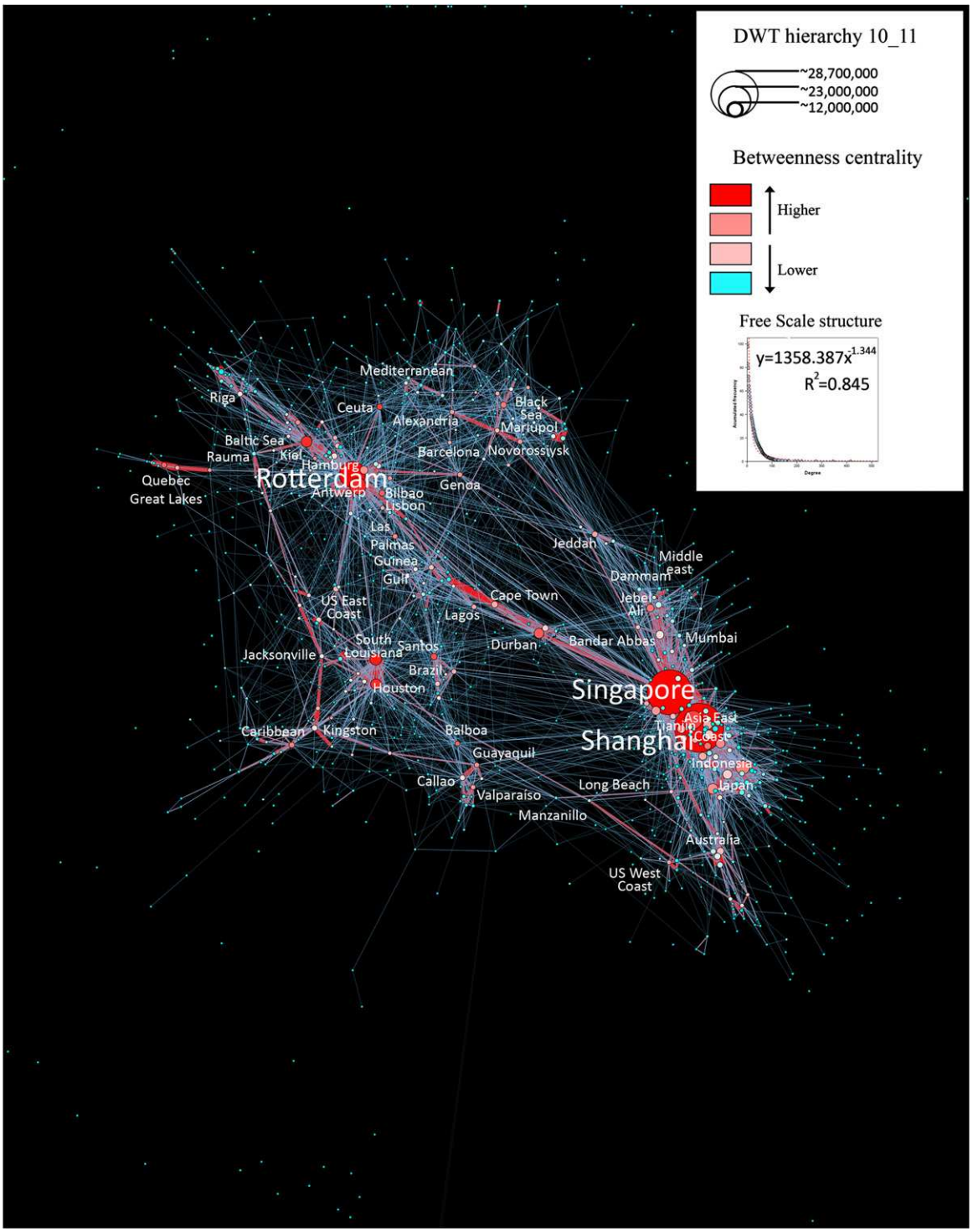

Fig. 6. Separation of 10_11 general cargo graph.
Source: Own elaboration.

The issues concerning graph density and the clustering coefficient mentioned above are clearly observable in the comparison established between the containership graphs (Figs. 7 and 8) and general cargo. The containerized trade network is demonstrably denser, due not only to the lower number of ports required for this mode of traffic, but also because of the intensity of the clusterization.

In the graph showing general cargo, three large clusters can be distinguished. This contrasts with the structure for containerized transport in which there is a clearly ring-like configuration with only a single entity exerting a powerful force of attraction: Hong Kong, Singapore, Rotterdam and all its dependent ports. The US East Coast appears to try to use its economic potential to attain the status of an independent hub, but the link between East Asia and North Europe remains the principal conglomerate for the whole of the containership structure. This said, there does exist a powerful link between the port line of Vancouver–Los Angeles–San Francisco (West Coast of North America) and the East Asian

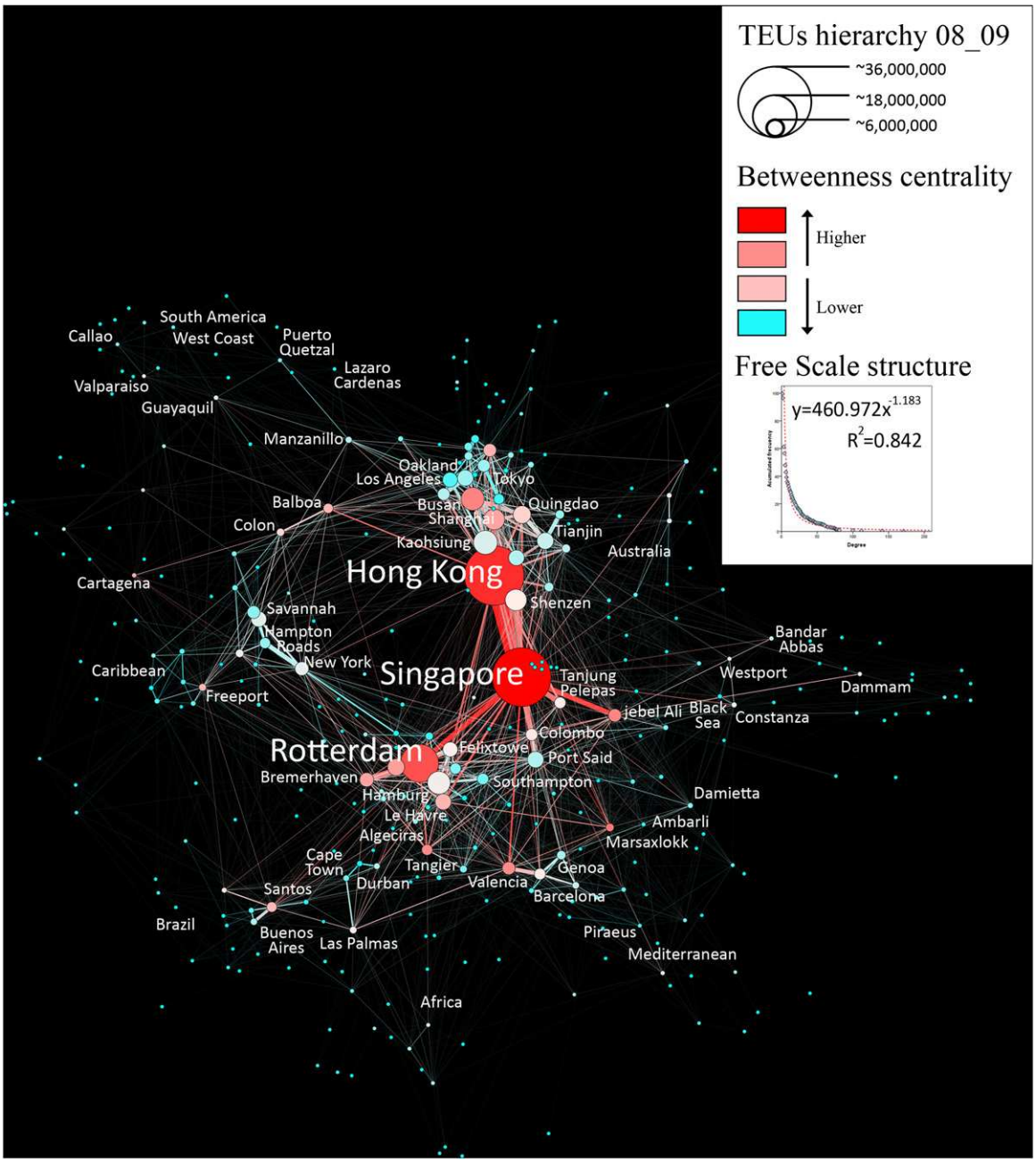

Fig. 7. Separation of 08_09 containership graph.
Source: Own elaboration.

hubs. This data suggests that the main supply routes for the US East Coast are the intermodal lines that transversally cross the country. This result reveals an area of potential future research which would aim to clarify how this railway transport structure will be affected when the new locks for the Panama Canal are opened. By referring to the separation graph it may be conjectured that the change will be both profound and global in nature, strengthening trans-world services and augmenting new clusters which are currently emerging. The most significant routes within this context are the supply line between the Caribbean and Santos–Buenos Aires, the West Coast of South America, and the new containerized trade area in the Middle East.

Using the information available it may be observed that containerships always sail from the East Asia hubs to the Northern Range, using the Singapore area as a trans-shipment service. What also stands out is how important the Middle Eastern ports of (Jeddah, Jebel Ali, Port Said, etc.) have become over the previous year. During the crisis they have been transformed into wealthy commercial intermediaries, generating their own demand structure and supplying a growing volume of goods to the Mediterranean and Black Sea ports, which are, in turn, immersed in their own intense regionalization processes.

Each of the network diagrams includes the relationship between each nodal degree and its aggregate frequency. In the four graphs, it can be observed that there are high frequencies for nodes where the level of degree is low and low frequencies for positions with high levels of connectivity. If the relationship between these two variables is consistent with a power law, then the networks are referred to as "scale free" networks. The exponent of each of the resultant power laws is a measure of the polarization within the system, that is, between the higher connectivity ports and subsidiary positions (Ducruet, 2010c). The

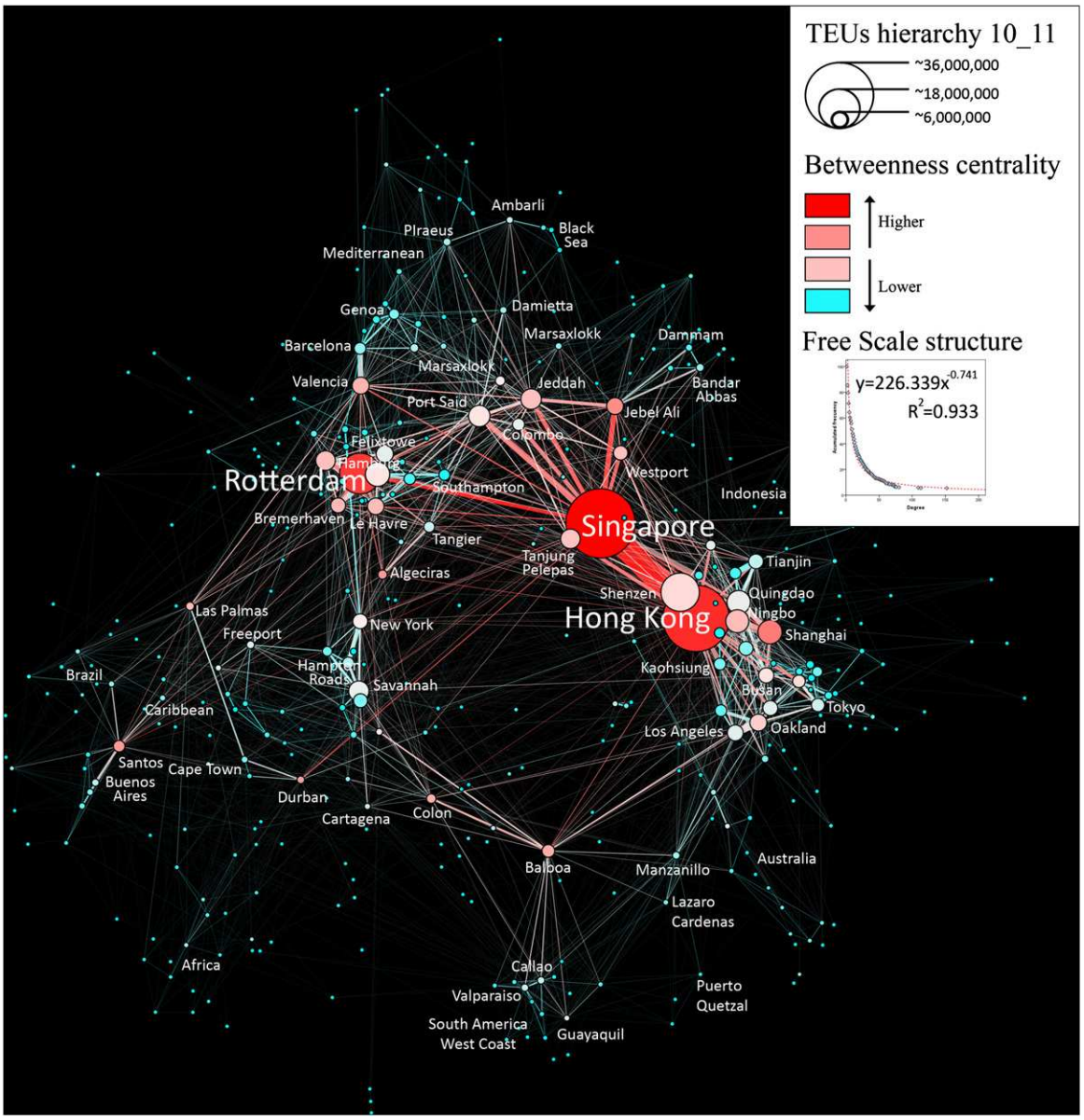

Fig. 8. Separation of 10_11 containership graph.
Source: Own elaboration.

precision of the "fit" obtained in the cases analyzed in this article is very high. For general cargo, the evolution of this exponent is from −1.301 to −1.344, which means that there is an increase in the level of integration between each of the port regions analyzed. In contrast, in containerized networks, the exponent evolves from −1.183 indicating the emergence of new alternative hubs.

8. Main and emergent ports

This section looks at which of the ports within the complex network are growing in terms of both regional and global relevancy. The analysis shows that there was an important recovery last year while, at the same time, there is evidence of a new configuration in the supply chain and the appearance of emerging clusters and regions of port coordination regions.

Table 5 provides a ranking of the most important ports in terms of their capacity. The table gives the rates of variation in capacity, and the degree and centrality over the period being considered.

On looking at the detailed study of each of the containership port variables, one sees that the variation in capacity for the big hubs almost always falls below the average rate of growth for the entire sample (72.3%), the exceptions being Shenzhen 104.1% growth, Ningbo 411.3%, Jeddah 238.6% and Westport 92.2%. Several ports exhibit negative growth rates i.e. Felixtowe (−0.8%), Busan (−33.8%) and Tianjin (−2.9%). The relative performance of the general cargo ports is much better and almost all of them find themselves above the mean variation rate (1.1%). However, there are negative growth rates for the ports of Yokohama (−7.3%), Jebel Ali (−5.3%) and Lianyungang (−13.1%).

The scenario contrasts sharply with the key indicator, rate of variation in degree, for which almost all of the ports exhibit declining rates. The only containership ports whose foreland increases are Shenzhen (5.9%), Shanghai (8.1%), Ningbo (46.8%), Jeddah (21.7%), and Tianjin (2.2%). This development clearly reflects port authority efforts to make up for a fall in demand

Table 5
Top 25 ranking of ports with higher throughput in 10_11. Variation rate of throughput, degree and centrality respect 09_10 and 08_09 (TEUs for containerships and DWT in General Cargo).
Source: Own elaboration.

Throughput ranking position	Containership				General cargo			
	Port	TEUs variation rate (%)	Degree variation rate (%)	Centrality variation rate (%)	Port	TEUs variation rate (%)	Degree variation rate (%)	Centrality variation rate (%)
1	Singapore	29.0	−11.1	−43.9	Shanghai	50.3	14.5	43.8
2	Hong Kong	32.2	−19.9	−56.0	Singapore	15.6	10.6	35.8
3	Rotterdam	18.1	−2.7	−44.7	Rotterdam	16.9	4.9	10.2
4	Chiwan (Shenzhen)	104.1	5.9	−33.0	Tianjin	37.7	18.6	45.9
5	Hamburg	12.4	−5.6	−18.8	Antwerp	9.3	0.5	18.1
6	Shanghai	18.8	8.1	−10.3	Moji	15.0	17.6	45.1
7	Qingdao	23.1	−7.8	−60.8	Port of S. Louisiana	12.7	14.9	23.5
8	Ningbo	411.3	46.8	201.9	Kiel	14.1	−1.2	41.0
9	Port Said	16.7	−25.0	−79.0	Houston	3.7	5.7	6.7
10	Jeddah	238.6	21.7	−3.8	Yokohama	−7.3	−11.2	−45.0
11	Savannah	16.0	−17.2	−70.5	Durban	10.9	−2.4	−13.0
12	Antwerp	26.7	−3.9	−58.1	Dalian	39.7	23.6	39.1
13	Tanjung Pelepas	38.5	−6.2	−42.2	Qingdao	25.4	9.2	−0.8
14	Felixstowe	−0.8	−25.0	−26.9	Kobe	1.9	−9.0	−51.7
15	Valencia	10.9	−5.3	−55.0	Hong Kong	4.6	10.9	−15.2
16	Oakland	12.6	−22.8	−57.6	Tanjung Priok	59.0	25.9	20.3
17	Jebel Ali	9.2	−15.4	−36.5	Saigon	2.3	−4.3	26.3
18	Le Havre	4.8	−7.1	−54.0	Hamburg	12.0	1.9	−2.0
19	Los Angeles	13.6	−21.4	−74.0	Bandar Abbas	46.4	−1.2	−48.0
20	Busan	−33.8	−25.0	−75.3	Busan	16.1	24.0	97.0
21	Yokohama	16.7	−18.1	−83.3	Jebel Ali	−5.3	15.1	90.5
22	Bremerhaven	7.7	−3.3	−17.4	Brisbane	12.8	−6.7	25.1
23	New York & New Jersey	14.6	−24.3	−68.5	Ulsan	23.6	11.1	25.0
24	Tianjin	−2.9	2.2	−17.3	Lianyungang	−13.1	−3.4	18.4
25	Westport (Malaysia)	92.2	−2.7	−19.4	Cape Town	22.5	15.2	29.7
Total ports average growth rate (%)		72.3	13.6	153.5		1.1	50.3	10.3
Std. deviation		1.880	0.669	7.988		5.423	1.524	63.765
Gini		0.851	0.863	0.327		0.906	0.933	0.965

by becoming the main suppliers for their growing internal markets.[5] With regard to the most important general cargo ports, in the main, the evolution of the degree has been much better than that for containerized cargo. However, all of these fall a long way short of the mean growth rate of 50.3%. The three that exhibit the most significant levels of growth are Dalian (23.6%), Tanjung Priok (25.9%) and Busan (24.0%).

The evolution of the rate of centrality clearly reveals a contraction in the level of containerized traffic in all the important ports, despite the fact that the mean variation in the rate of centrality increases by 153.5%. The ports in which decreases are most pronounced are Yokohama (−83.3%), Busan (−75.3%) and Los Angeles (−74.0%). This decline in the centrality of the ports belonging to the Transpacific routes suggests that secondary supply lines have been sacrificed, i.e. those that were less profitable and which could not be maintained over the period studied due to problems of congestion in the port of Los Angeles,[6] and to a general decline in Trans-Pacific transit.[7] The port of Ningbo is particularly noteworthy since it registered a remarkable rise in centrality of 201.9%, much higher than average. This set of terminals emerges from the Shanghai subsidiary hub and plays a very important role as a complementary trans-shipment node and helps to free up Shanghai. This development falls within the framework of Chinese governmental strategies to improve the production centre located along the Yangtze river.[8] The evolution of the centrality in general cargo ports reveals a highly significant increase for almost all of the most important ports. There are, however, several exceptions: Yokohama (−45%), Durban (−13%), Kobe (−51.7%), Hong Kong (−15.2%), Hamburg (−2%) and Bandar Abbas (−48%).

Despite the more favorable results for the evolution of general cargo transport, most of the important ports have not performed well in terms of growth. This suggests that emergent nodes are located in areas with discreet annual throughput. Hence, currently, there are ports with moderate or low operational capacities which are in the process of carrying out improvements in their infrastructures or in their draft, and these ports aim to be key players in the reconfigured network of international maritime transport. The emergent ports have been selected from those that exhibit the most relevant rates of degree and centrality, the chosen ports being the ones that are ranked highest when the combined variables of degree and centrality are taken into account when compared to position (Tables 6 and 7 and Fig. 9).

[5] 'Too close for comfort', *Containerisation International*, June 2010.
[6] 'LA terminals add night gates', *Containerisation International*, October 2010.
[7] 'On the way up', *Containerisation International*, May 2010.
[8] 'Pushing the boundaries', *Containerisation International*, February 2009.

Table 6
Top 27 ranking of emerging containership ports.
Source: Own elaboration.

Position[a]	Name	Country	Throughput			Degree		Betweenness centrality	
			Position in TEUs throughput ranking	Total ($\times 1000$)	Variation rate	Total	Variation rate	Total	Variation rate
4	Dar es Salaam	Tanzania	203	97	2.4	13	1.6	274.9	78.8
4	Mersin	Turkey	138	401	1.4	31	1.8	454.1	37.0
7	Pointe-Noire	Congo	232	46	1.0	13	1.2	458.1	25.4
9	Ensenada	Mexico	184	143	3.8	9	1.3	5.4	11.9
13	Cochin	India	256	25	1.2	8	1.0	4.4	9.6
13	S. Franco. do Sul	Brazil	163	212	0.1	12	0.7	46.5	20.1
15	Puerto Cortes	Honduras	224	56	1.6	8	1.0	66.8	3.5
17	Ambarli	Turkey	70	1322	1.2	40	0.7	757.9	8.5
17	Roberts Bank	Canada	52	1943	0.6	18	0.5	9.8	11.7
18	Mombasa	Kenia	189	125	1.3	11	0.6	214.7	6.5
18	Taichung	Taiwan	219	66	−0.1	10	0.4	39.2	50.5
18	Nagoya	Japan	56	1784	5.8	19	0.5	62.7	22.9
18	Manila	Philipp	130	429	1.1	24	0.7	78.6	3.3
24	Tanjung Priok	Indonesia	145	341	0.9	18	0.8	58.4	1.6
25	Pyeong Taek	S. Korea	179	173	0.3	7	0.4	3.7	11.3
27	Johor	Malaysia	170	203	0.2	19	0.9	77.1	1.2
27	Napier	N. Zealand	166	205	0.0	12	0.5	280.5	1.8
28	Sepetiba	Brazil	91	889	0.0	28	0.4	380.5	3.0
29	Ningbo	China	8	10,277	4.1	69	0.5	2176.0	2.0
31	Karachi	Pakistan	92	857	3.6	17	0.3	71.5	4.7
31	Dartmouth	Canada	178	175	2.8	9	0.8	2.0	0.6
31	Setubal	Portugal	245	33	1.3	10	0.4	251.3	2.1
33	Venice	Italy	182	148	1.8	9	0.3	97.7	3.9
33	Malaga	Spain	105	628	0.7	23	0.4	444.5	1.5
34	Gdansk	Poland	128	433	3.0	7	0.2	68.7	29.6
36	El Dekheila	Egypt	129	430	0.3	28	0.6	318.9	0.6
36	Cristobal	Panama	75	1252	0.4	43	0.4	1372.8	1.1
Total average					0.723		0.136		1.535
Std. deviation					1.880		0.669		7.988
Gini					0.851		0.863		0.327

[a] Mean of the degree and centrality variation rate ranking position.

This section presents the set of emergent ports, that is, the ports that have best evolved over the period analyzed. One way of approaching this might have been to establish efficiency rankings for the ports by using Data Envelopment Analysis (DEA), and this is undoubtedly an area in which future research will make great strides. However, this study takes an approach which is conceptually much simpler involving the construction of a mean ranking. This allows the analysis to take into account the ports that have exhibited the greatest levels of variation in terms of both degree and centrality. In addition, the ranking also highlights those ports whose growth in centrality has been limited but for whom connectivity has increased, or conversely, those whose centrality has not increased significantly but which have become important regional hubs.

The analysis looks first at container shipping. Of the ten ports that have grown most in terms of both in degree and centrality, three are in Africa, three in Central America and two in Turkey. This data, which looks at the principal emergent regions, reveals that the developing countries with relatively high rates of GDP are those whose market positions are improving in consonance with their dynamic economic status.

Of the emergent ports, the most important is Dar Es Salaam in Tanzania. During the 10_11 period this port registered a score of 13 for degree and 274.9 for centrality, values which diverge significantly from the overall average values for the sample (16 and 318.9, respectively). Second in the ranking came the Turkish port of Mersin which obtained an above-average score for both degree (31) and centrality (545.1). The importance in the score obtained for centrality reflects the prominent position of the port with respect to transit operations related to the congested entrance to the Suez Canal. The third port on the list is Pointe-Noire, which is located in the Gulf of Guinea, and is reinforcing an advantageous position with respect to the traffic catchment area made up of the East Asia–Europe lines that go round the Cape of Good Hope.

The ranking reveals that there are some Central American ports which have grown significantly. The port that really stands out in this area is Ensenada in Mexico, for which both degree and centrality are low, but which registered a substantial operational throughput of 184,000 TEUs for the period analyzed. This data reflects the existence of a recently built terminal that has successfully become operational.[9] Another port operating in this area and located in the Caribbean is the Puerto Cortes terminal, in Honduras. The most important port within the region, however, is Cristobal, located on the Caribbean gateway to the Panama Canal, a port which has very high indicators for both degree (43) and for centrality (1372). This terminal achieved a throughput of 1,372,000 TEUs for the time period considered, which is well over the mean throughput of 1,180,000 TEUs. Given this somewhat exceptional scenario, it is hardly surprising that the Panama Port Authority is trying to prevent other Caribbean ports (Kingston, Altamira, Caucedo, Miami or Freeport) from absorbing the containerized traffic using the Canal, by stimulating the growth in the demand within its hinterland and by establishing new hub&spoke activities through the reinforcement of their main container ports.

Brazil also has a special presence in the over-populated area of Santos–Rio de Janeiro, represented on the list emergent ports and their terminals located at Sao Francisco do Sul and Sepetiba.

[9] 'A long-overdue lift', *Containerisation International*, November 2010.

Table 7
Top 27 ranking of emerging general cargo ports.
Source: Own elaboration.

Position[a]	Name	Country	Throughput			Degree		Betweenness centrality	
			Position in DWTs throughput ranking	Total ($\times$1000)	Variation rate	Total	Variation rate	Total	Variation rate
2	Swinoujscie	Poland	387	406	47.9	28	13.0	306.8	1183.4
10	Djen-Djen	Algeria	810	82	9.2	14	6.0	42.6	180.6
10	Chimbote	Peru	443	329	36.7	17	7.5	285.1	142.6
12	Ishinomaki	Japan	608	181	7.4	17	3.3	189.0	637.2
13	Batumi	Georgia	535	237	9.2	18	8.0	291.9	52.0
13	Dahej	India	611	177	2.2	17	3.3	108.7	349.2
17	Trois-Rivieres	Canada	263	729	1.6	45	4.0	2388.5	55.7
18	Sept-Iles	Canada	519	250	3.8	19	3.8	1007.2	73.4
19	Mocamedes	Angola	473	297	12.8	19	5.3	68.6	47.2
21	Porto Vesme	Italy	798	85	2.4	16	2.2	403.0	165.7
22	Portland	Australia	270	706	5.8	23	1.9	1084.6	196.8
22	Paita	Peru	624	170	2.7	14	1.8	466.0	371.3
23	Nakhodka	Rusia	579	199	4.3	19	2.2	83.1	155.4
23	Palm Beach	USA	711	122	2.9	14	2.5	1252.7	49.0
24	Masan	S. Korea	124	1513	111.1	43	20.5	506.3	14.7
26	Martas	Turkey	526	243	5.7	23	2.8	221.7	37.0
26	Lorient	France	733	111	2.6	15	4.0	40.1	24.7
28	Mombasa	Kenia	322	537	2.2	26	2.3	248.5	44.6
29	Limay	Philippines	722	116	3.7	13	2.3	41.1	37.3
29	Belawan	Indonesia	307	577	0.9	15	1.5	40.2	165.4
30	Contrecoeur	Canada	606	181	2.6	17	2.4	307.4	29.6
30	Gioia Tauro	Italy	391	398	0.4	18	1.6	144.5	150.1
31	Monrovia	Liberia	495	272	5.2	20	2.3	318.5	27.3
33	Hakata	Japan	544	229	6.4	20	5.7	139.5	12.1
33	Abu Dhabi	UAE	267	710	3.6	31	5.2	164.9	12.4
36	Port Rashid	UAE	528	241	2.7	14	1.3	41.6	117.4
36	Coatzacoalcos	Mexico	699	129	0.2	13	1.2	1342.8	162.0
Total average					1.050		0.503		10.320
Std. deviation					5.423		1.524		63.765
Gini					0.906		0.933		0.965

[a] Mean of the degree and centrality variation rate ranking position.

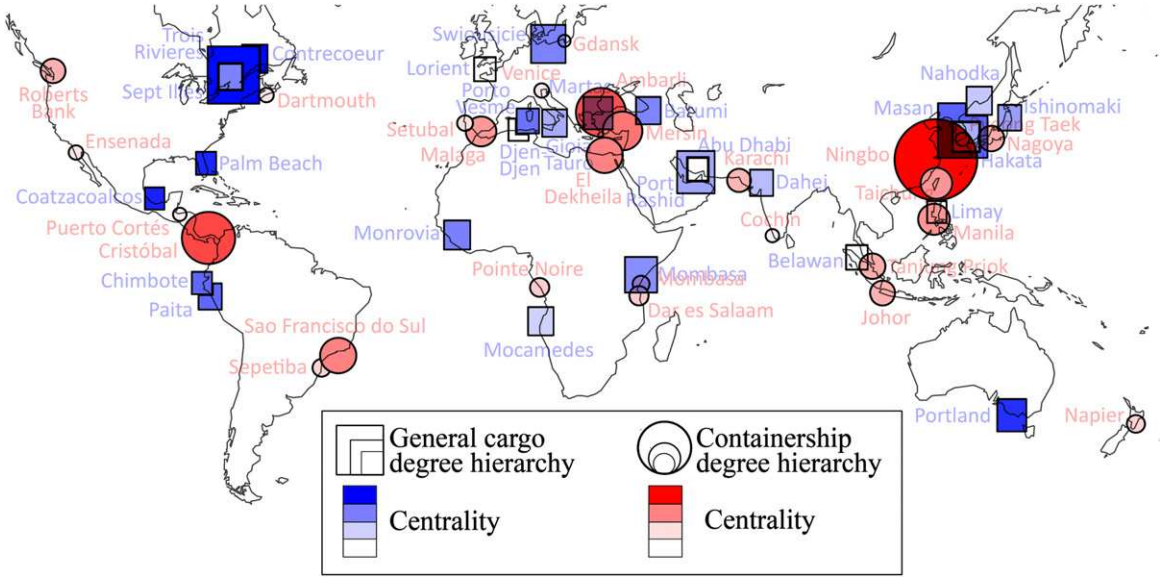

Fig. 9. Emerging ports in 09_11.
Source: Own elaboration.

Developed countries are present in many of the general cargo transport network's main positions, but emergent economies are well-represented in the general ranking of ports whose growth is ascendant. First and foremost the Polish port of Swinousjcie should be highlighted, a port with no significant variation in degree (13) but a significant variation in centrality (1183.4). This, combined with a discreet level of dwt throughput, i.e. below average, reflects successful policies for the capture of traffic, probably awaiting the acquisition of additional, profitable regular services. This contrasts sharply with the Algerian port of Djen-

Djen, which has very low scores for both degree and centrality, but a high volume of throughput, which is probably because it has managed to establish a regular geographically stable supply line. The Peruvian ports of Chimbote and Paita, with above-average throughput, but lower values of centrality and degree, are very important ports on the Pacific Ocean and have strong recently-established supply lines. The largest area of development is located in one of the most important industrial areas in the world, the Great Lakes–San Lorenzo River line, the competitor ports for these important flows of goods and raw materials being Canadian. Here the ports that stand out are, Trois Rivieres, which has a very high score for both degree (45) and centrality (2388), Sept Illes with a degree of 19 and centrality of 1007.2, and at a certain distance Contrecoeur. These levels of centrality are typical of continental waters for which the geographical diversification and rerouting of traffic is evidently impossible.

9. Conclusions

The first conclusion of this research is that the general cargo network is relatively strong when compared to the global containerized transport system. This is confirmed by the main indicators since the graph density is low, as are the coefficients for clusterization and the "scale free" power laws whose exponential is also low. The values for these variables reveal that there is a slight hub-dependency, which means that there fewer subsidiary relations between ports and, as a result, better market opportunities.

The second conclusion to be gleaned from the separation graphs is that goods shipped in general cargo vessels are much more likely to be transported to a given destination using a variety of different routes, which has a bonus effect in the cost of maritime transport.

Thirdly, the containership market remains almost entirely focused on servicing East Asia–Europe and East Asia–West Coast US routes; hence it becomes still difficult for ports that distance themselves from these lines to obtain economies of scale. Nevertheless, on looking at the gravitational models, the TEU volume transported clearly reveals incipient clusterization processes in the containership routes, particularly those for the Caribbean Sea, the West Coast of South America, and for the Middle East hubs.

Finally, it is worthwhile drawing a conclusion with respect to a hypothesized polarization that suggests that the developed economies are positive related to higher levels of containerized traffic, and developing economies with higher levels of general cargo transport. The former have been more greatly affected by the economic crisis, which has led the containership transport industry into a difficult period of alliances, closures and commercial reorientation. Currently, there seem to be some signs of recovery with slight improvements in market quota for container shipping. General cargo transport remains a highly important logistical alternative however; demand is stable and there is worldwide distribution, not only for low cost goods, but also for sophisticated machinery and manufacturing and industrial products which require high levels of care and efficiency when it comes to loading and unloading.

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